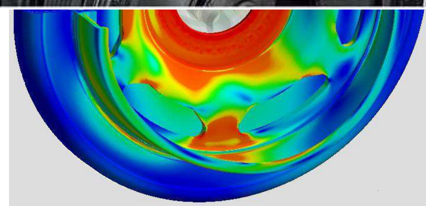
Official Report - Engineering Calculations



Mesh Metrics in ANSYS WB 13.0

Dr. Árpád Veress, T/RDA2

05. 02. 2013.

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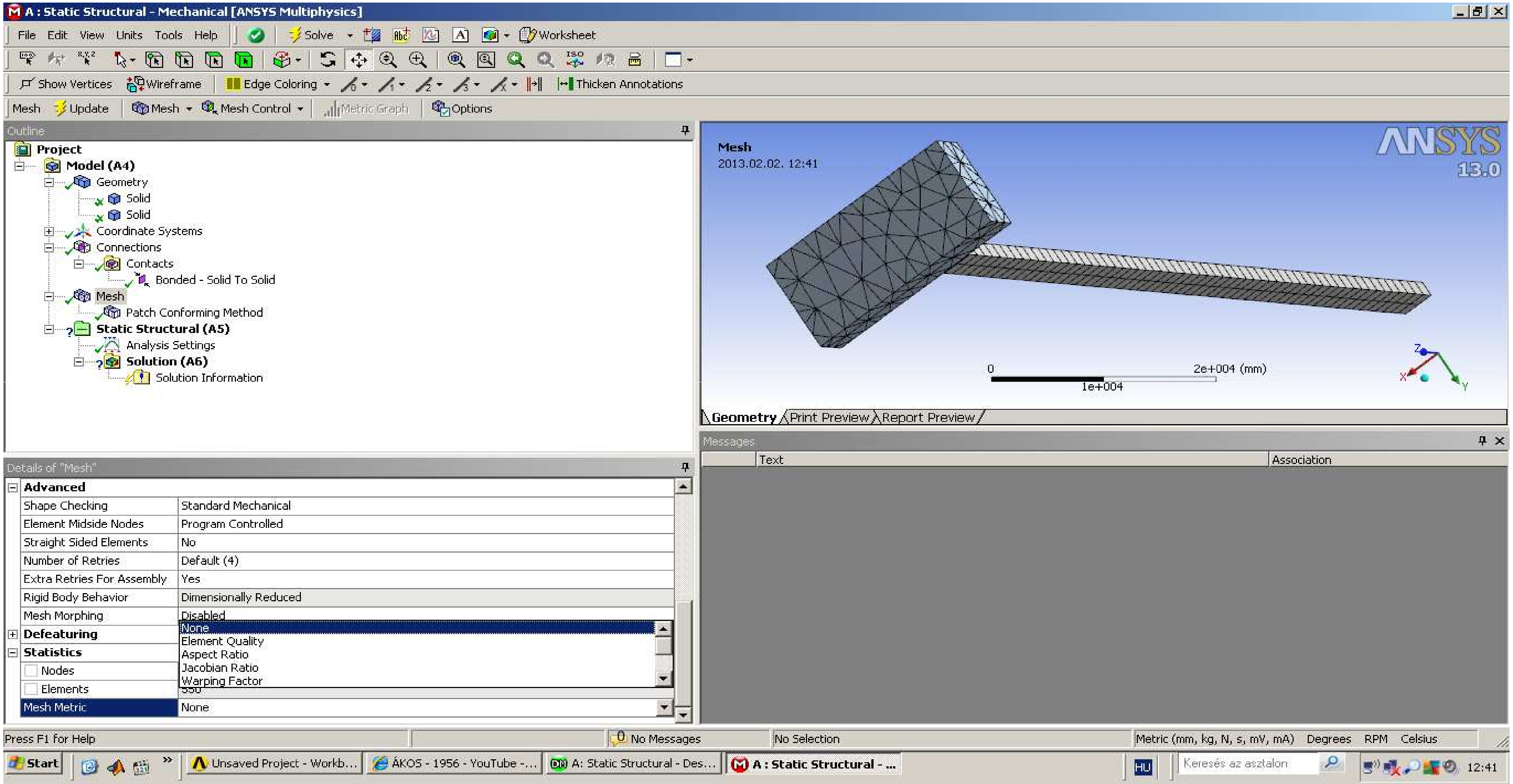
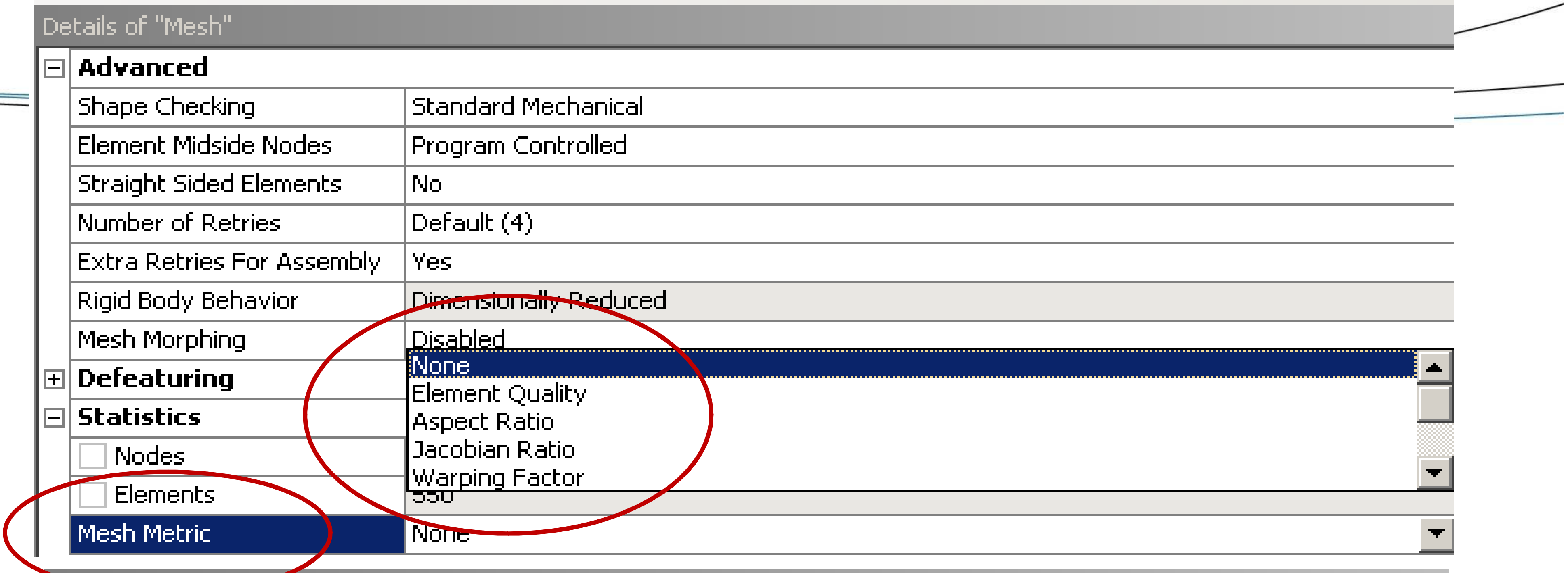
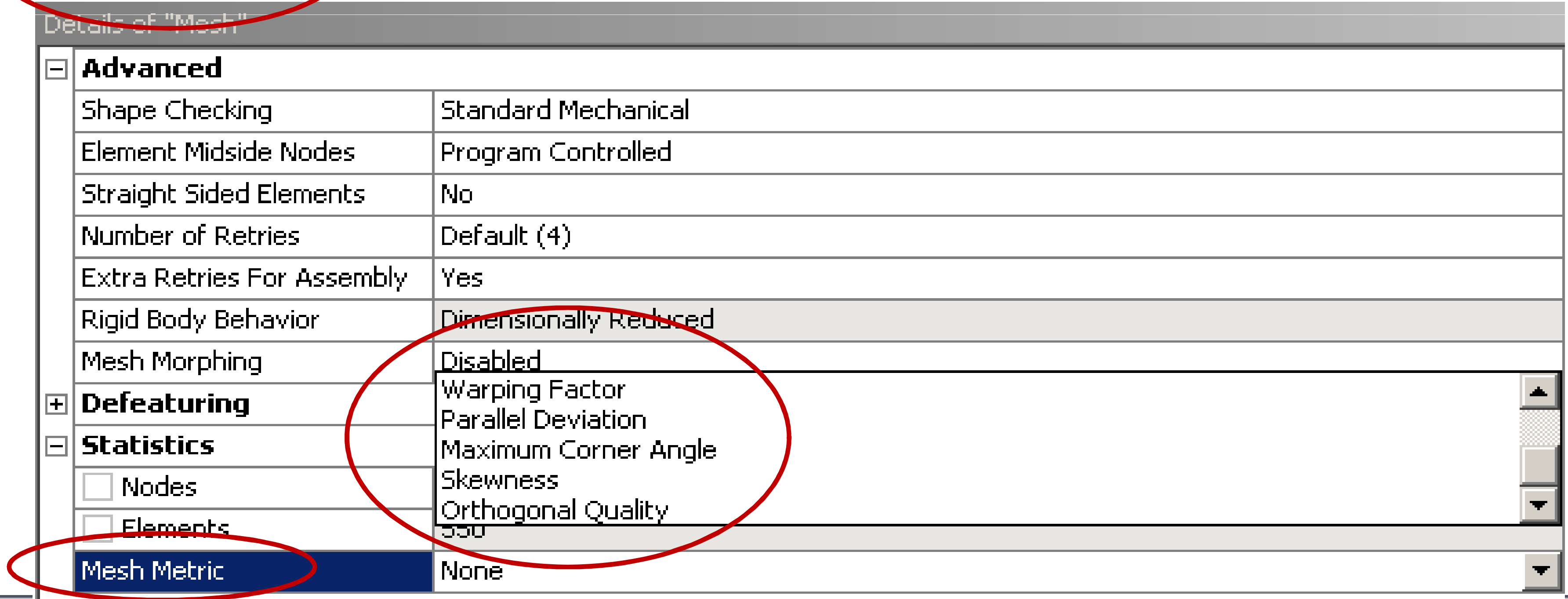
Fatigue Evaluation in Haigh Diagram




Details of "Mesh"
Advanced
Shape Checking
Standard Mechanical
Element Midside Nodes
Program Controlled
Straight Sided Elements
No
Number of Retries
Default (4)
Extra Retries For Assembly
Yes
Rigid Body Behavior
Dimensionally Reduced
Mesh Morphing
Disabled
Defeaturing
Statistics
Nodes
Elements
Mesh Metric
None
None
Element Quality
Aspect Ratio
Jacobian Ratio
Warping Factor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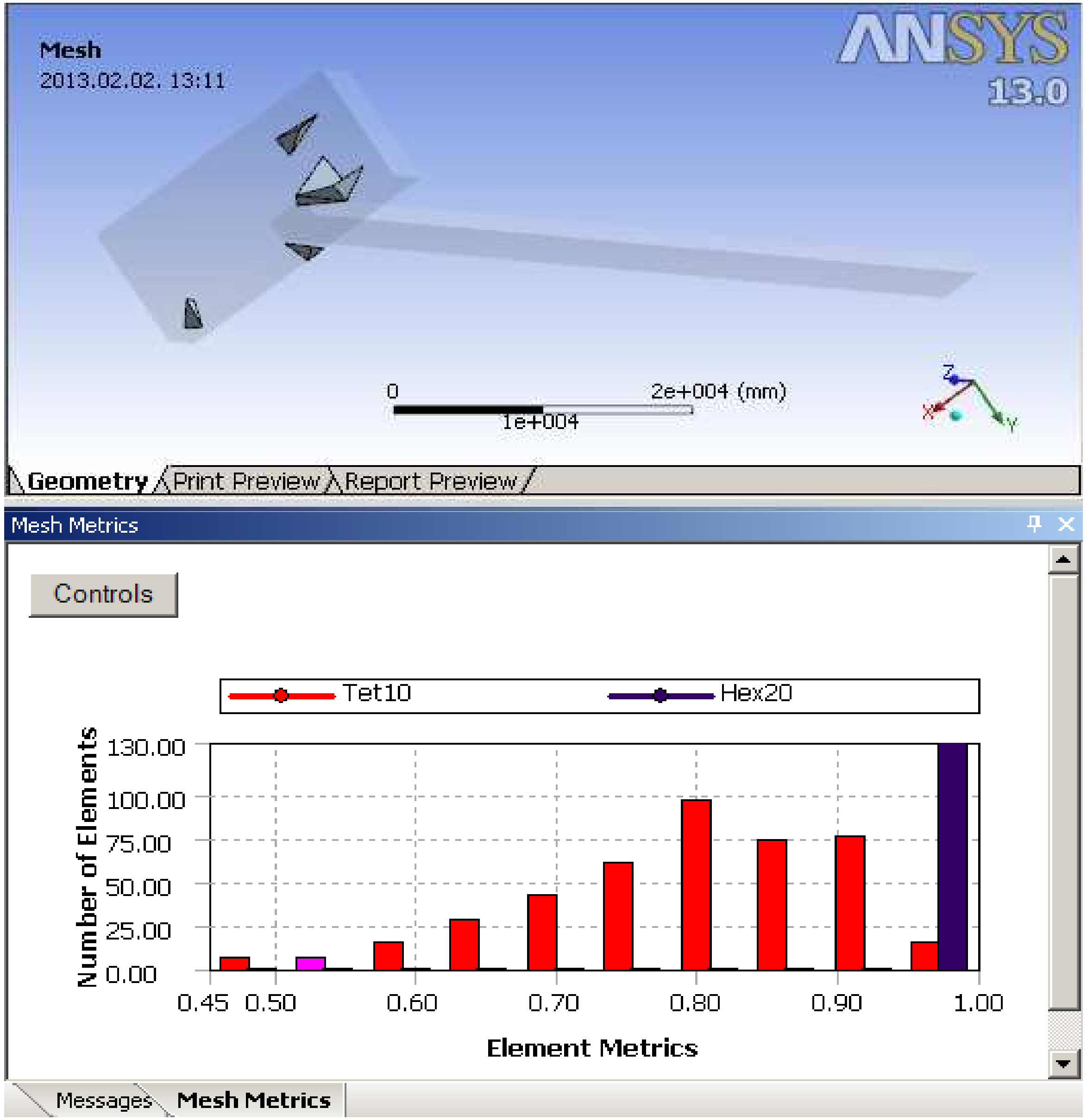
Warping Factor
Parallel Deviation
Maximum Corner Angle
Skewness
Orthogonal Quality

Element Quality



A quality factor is computed for each element of a model (excluding line and point elements). The Element Quality option provides a composite quality metric that ranges between 0 and 1. This metric is based on the ratio of the volume to the edge length for a given element. A value of 1 indicates a perfect cube or square while a value of 0 indicates that the element has a zero or negative volume.

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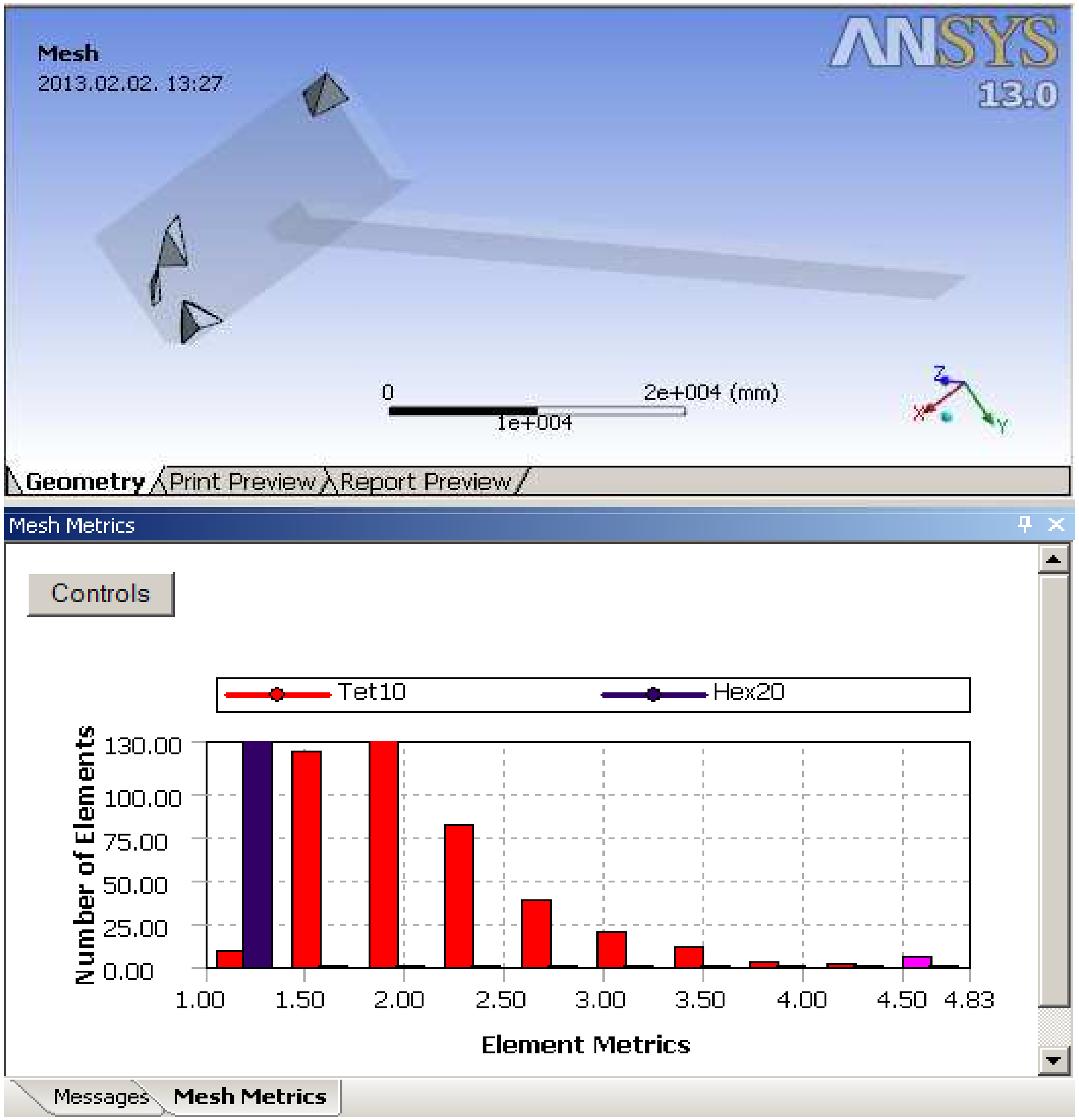
Aspect Ratio for Triangles



A line is constructed from one node of the element to the midpoint of the opposite edge, and another through the midpoints of the other 2 edges. In general, these lines are not perpendicular to each other or to any of the element edges. Rectangles are constructed centred about each of these 2 lines, with edges passing through the element edge midpoints and the triangle apex. These constructions are repeated using each of the other 2 corners as the apex. The aspect ratio of the triangle is the ratio of the longer side to the shorter side of whichever of the 6 rectangles is most stretched, divided by the square root of 3.

Aspect Ratio for Triangles

Figure: Triangle Aspect Ratio Calculation

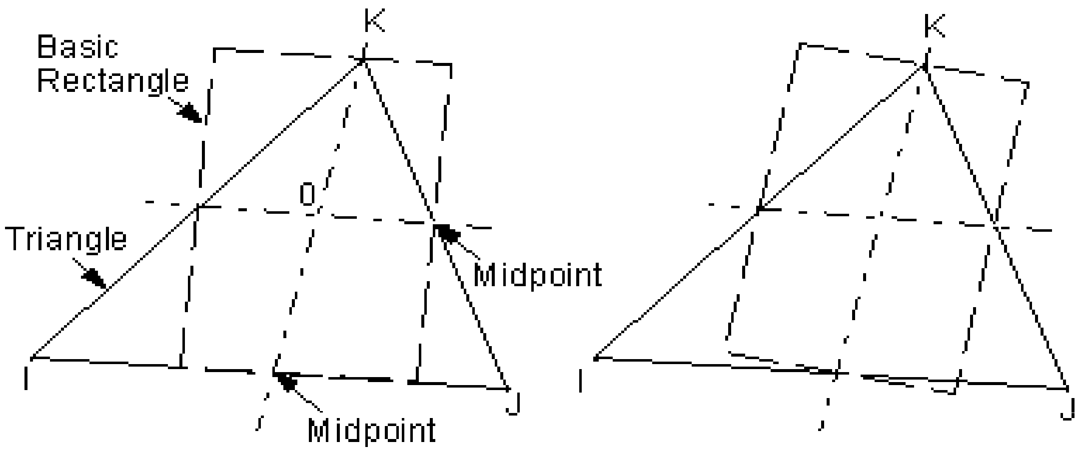


Figure: Aspect Ratios for Triangles

A line is constructed from one node of the element to the midpoint of the opposite edge, and another through the midpoints of the other 2 edges. In general, these lines are not perpendicular to each other or to any of the element edges. Rectangles are constructed centred about each of these 2 lines, with edges passing through the element edge midpoints and the triangle apex. These constructions are repeated using each of the other 2 corners as the apex. The aspect ratio of the triangle is the ratio of the longer side to the shorter side of whichever of the 6 rectangles is most stretched, divided by the square root of 3.

Quadrilateral Aspect Ratio

Figure: Quadrilateral Aspect Ratio Calculation

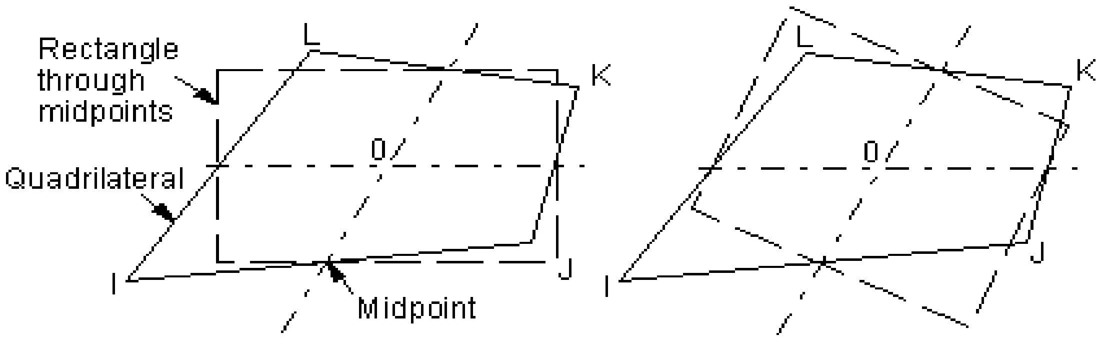
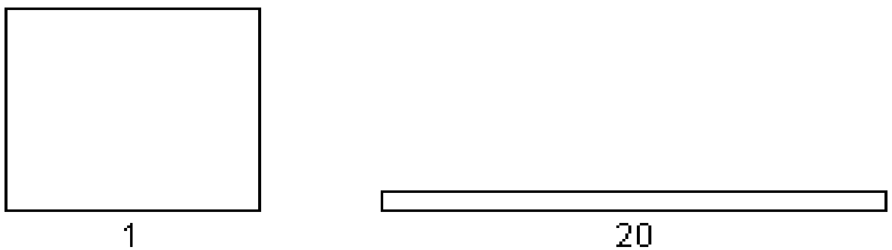


Figure: Aspect Ratios for Quadrilaterals



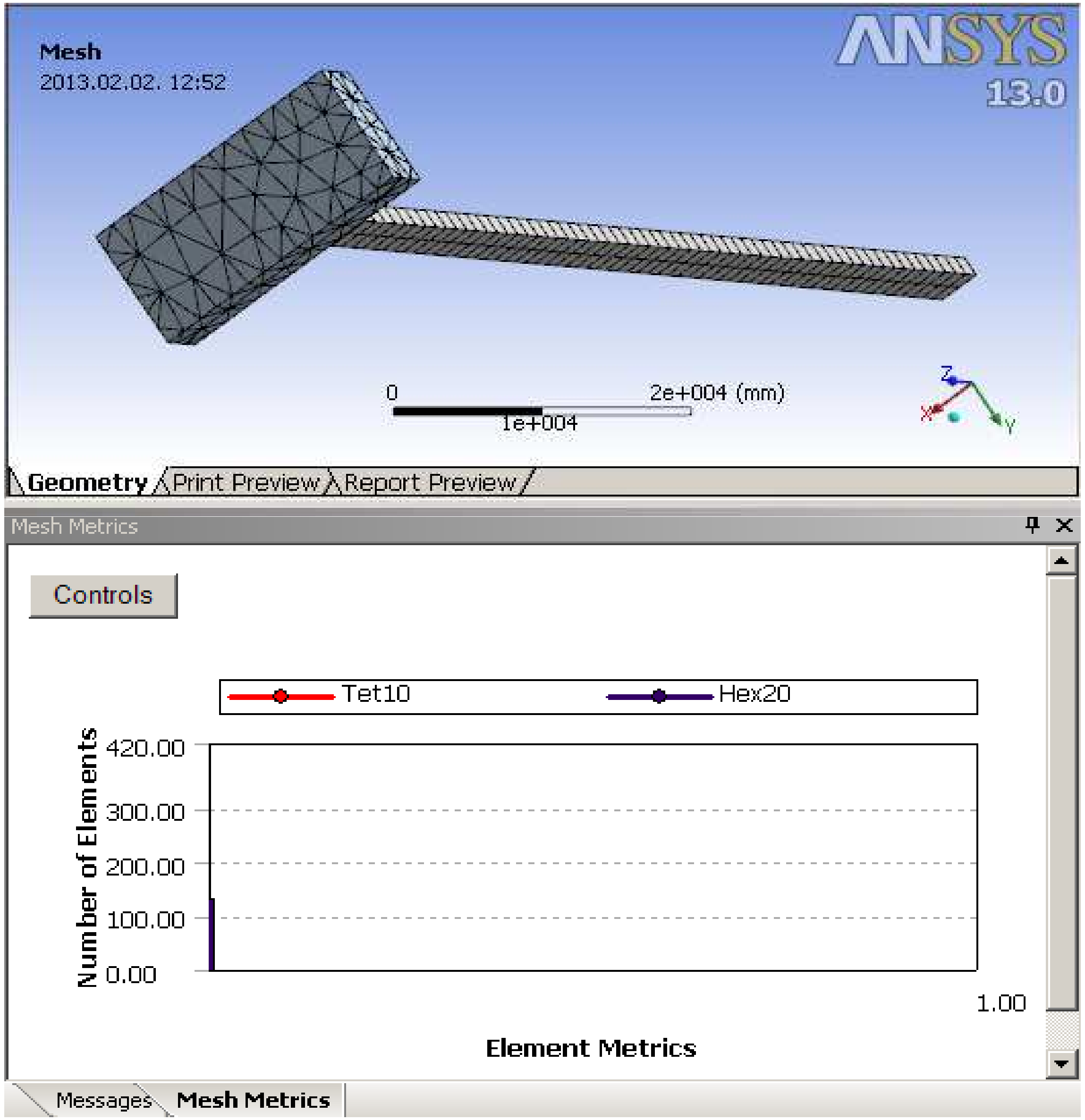
If the element is not flat, the nodes are projected onto a plane passing through the average of the corner locations and perpendicular to the average of the corner normals. The remaining steps are performed on these projected locations.

Two lines are constructed that bisect the opposing pairs of element edges and which meet at the element center. In general, these lines are not perpendicular to each other or to any of the element edges.

Rectangles are constructed centered about each of the 2 lines, with edges passing through the element edge midpoints. The aspect ratio of the quadrilateral is the ratio of a longer side to a shorter side of whichever rectangle is most stretched.

The best possible quadrilateral aspect ratio, for a square, is one. A quadrilateral having an aspect ratio of 20 is shown in Figure.

Jacobian Ratio



Jacobian ratio is computed and tested for all elements except triangles and tetrahedra that (a) are linear (have no midside nodes) or (b) have perfectly centred midside nodes. A high ratio indicates that the mapping between element space and real space is becoming computationally unreliable.

Figure: Jacobian Ratios for Triangles

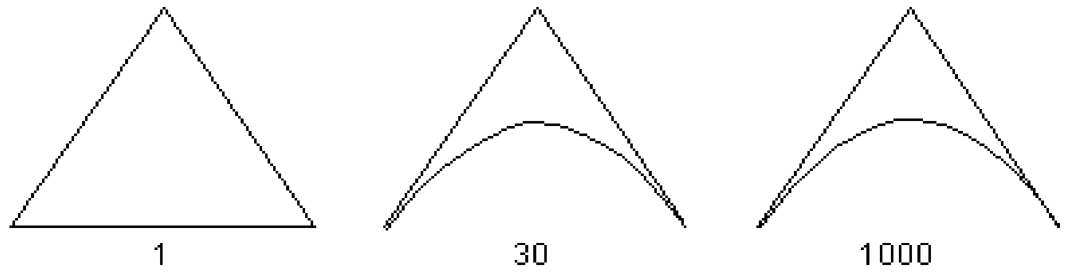


Figure: Jacobian Ratios for Quadrilaterals

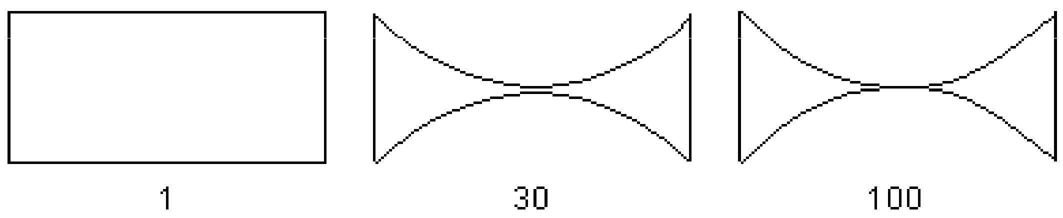
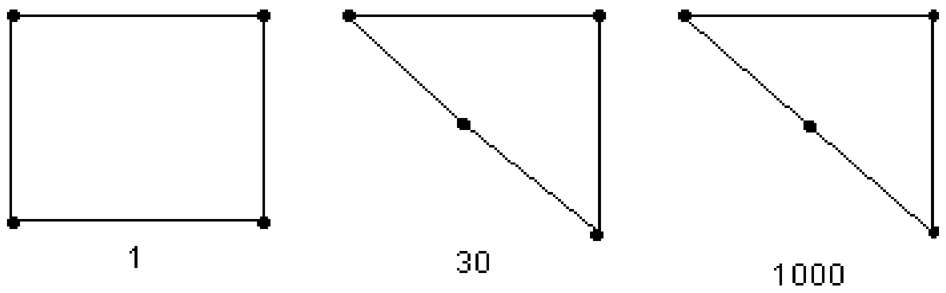
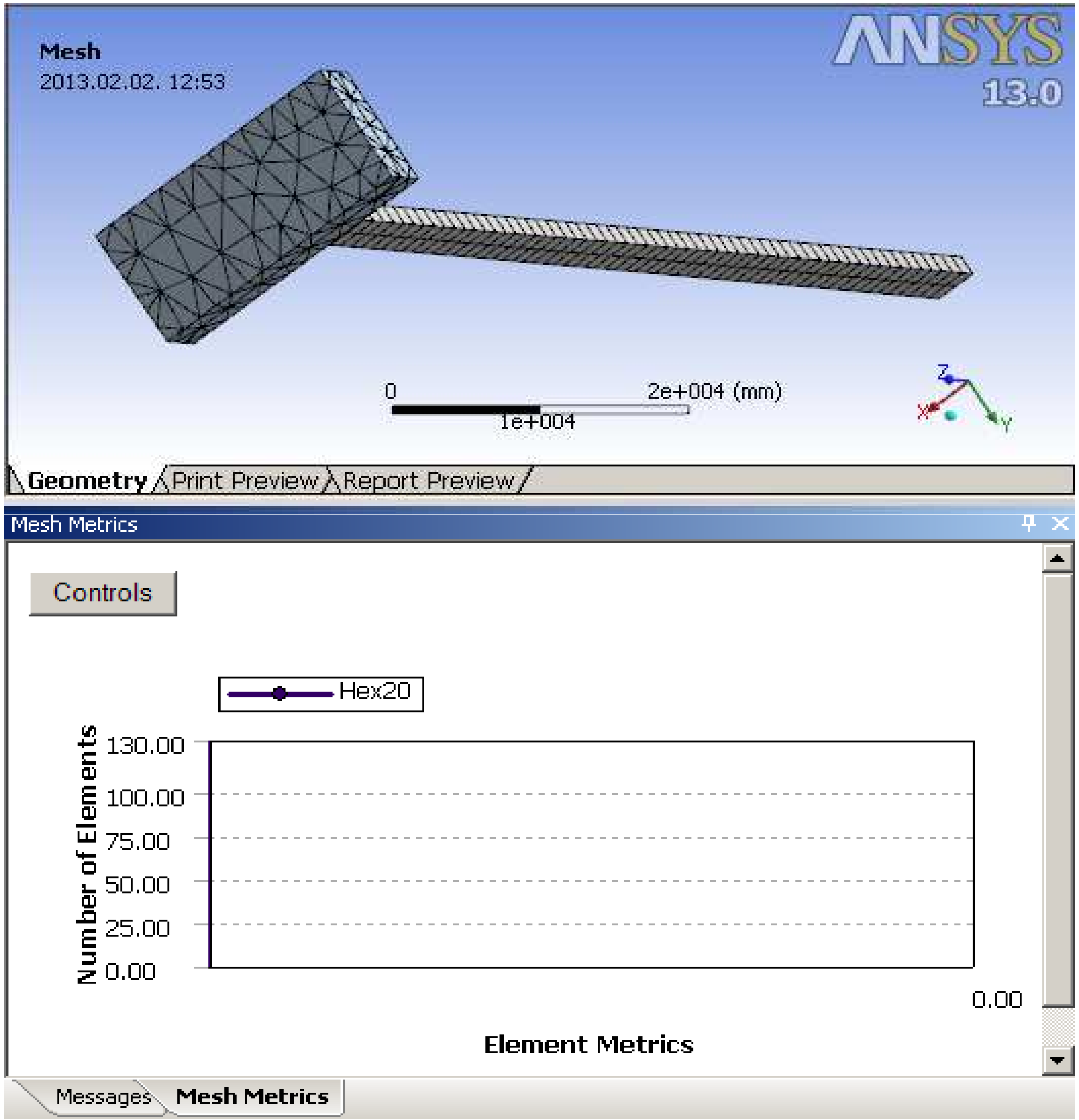


Figure: Jacobian Ratios for Quadrilaterals



Jacobian ratio is computed and tested for all elements except triangles and tetrahedra that (a) are linear (have no midside nodes) or (b) have perfectly centred midside nodes. A high ratio indicates that the mapping between element space and real space is becoming computationally unreliable.

Warping Factor



The warping factor for a 3-D solid element face is computed as though the 4 nodes make up a quadrilateral shell element with no real constant thickness available, using the square root of the projected area of the face.

Warping Factor

Figure: Quadrilateral Shell Having Warping Factor

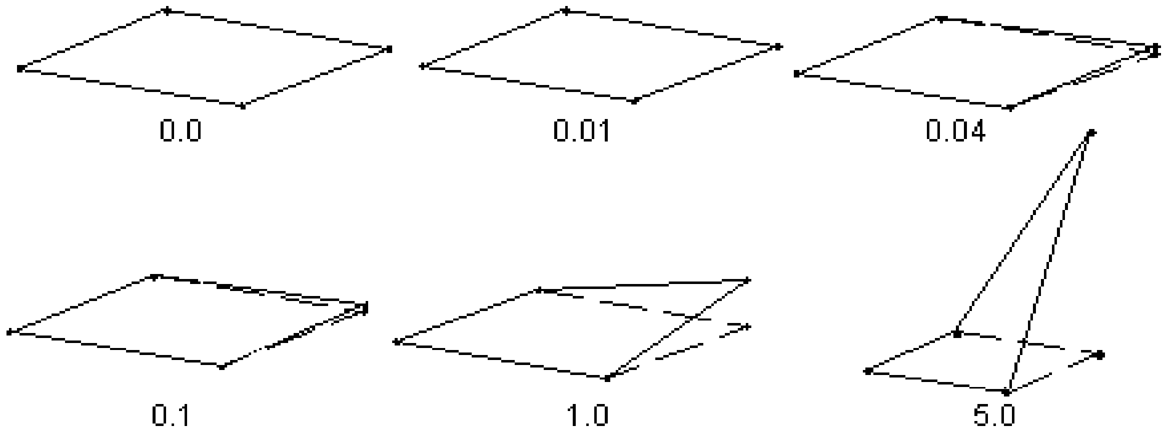
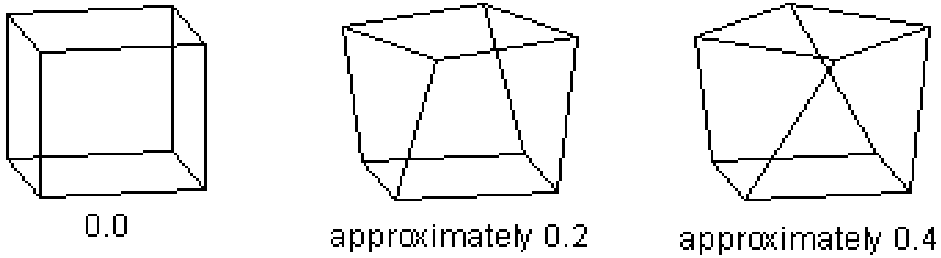
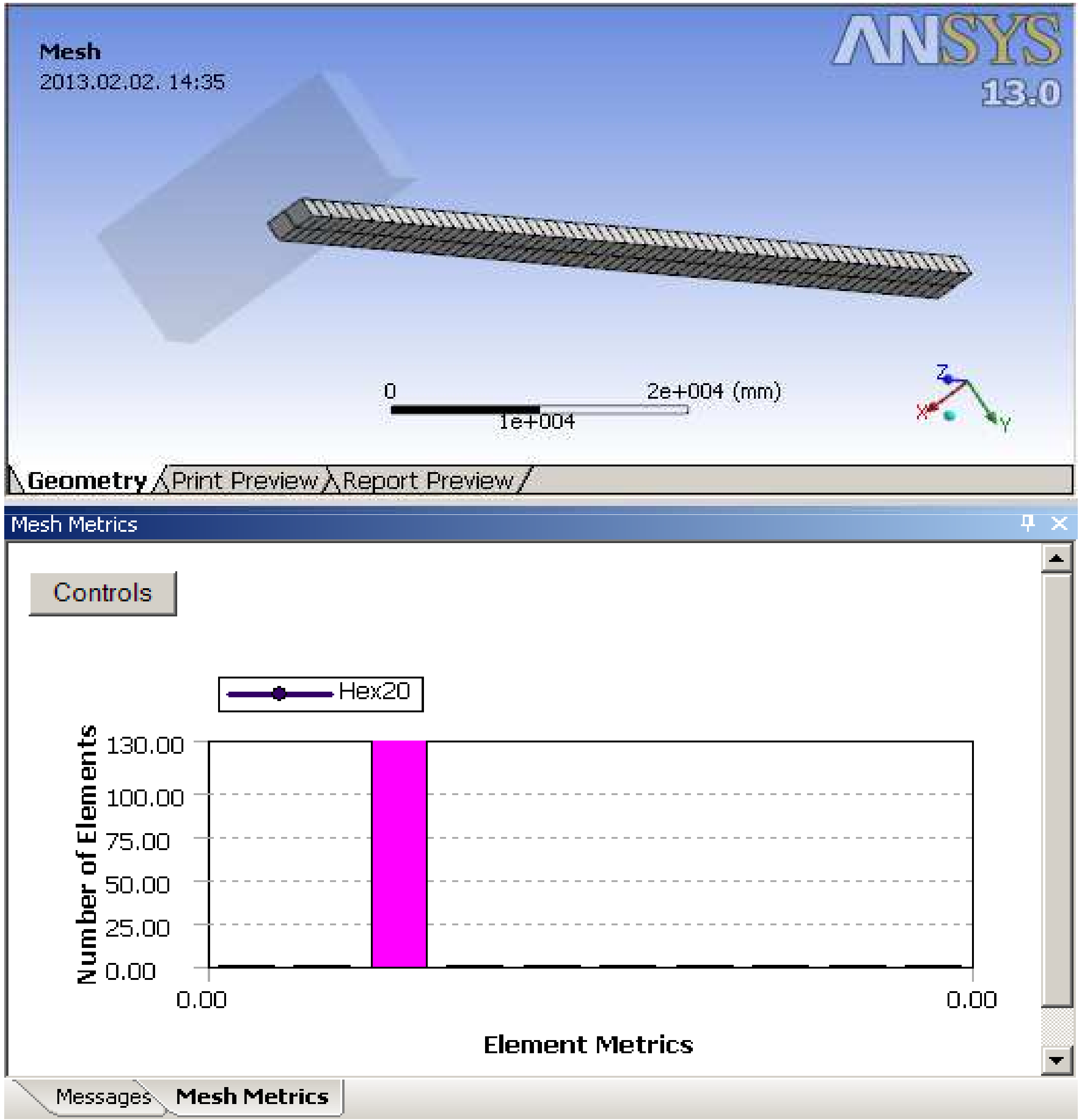


Figure: Warping Factor for Bricks



The warping factor for a 3-D solid element face is computed as though the 4 nodes make up a quadrilateral shell element with no real constant thickness available, using the square root of the projected area of the face.

Parallel Deviation



Ignoring midside nodes, unit vectors are constructed in 3-D space along each element edge, adjusted for consistent direction. For each pair of opposite edges, the dot product of the unit vectors is computed, then the angle (in degrees) whose cosine is that dot product. The parallel deviation is the larger of these 2 angles. (In the illustration above, the dot product of the 2 horizontal unit vectors is 1, and acos (1) = 0°. The dot product of the 2 vertical vectors is 0.342, and acos (0.342) = 70°. Therefore, this element's parallel deviation is 70°.)The best possible deviation, for a flat rectangle, is 0°. Figure Figure: Parallel Deviations for Quadrilaterals shows quadrilaterals having deviations of 0°, 70°, 100°, 150°, and 170°.

Parallel Deviation

Figure: Parallel Deviation Unit Vectors

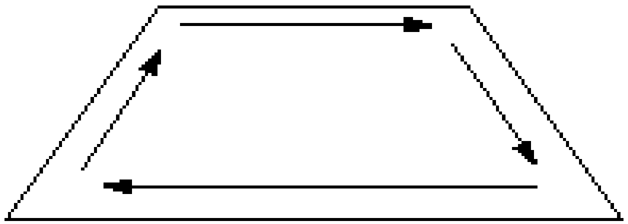
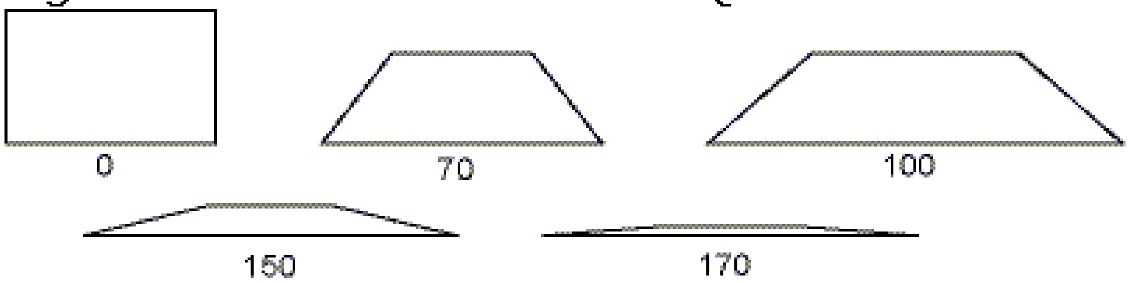
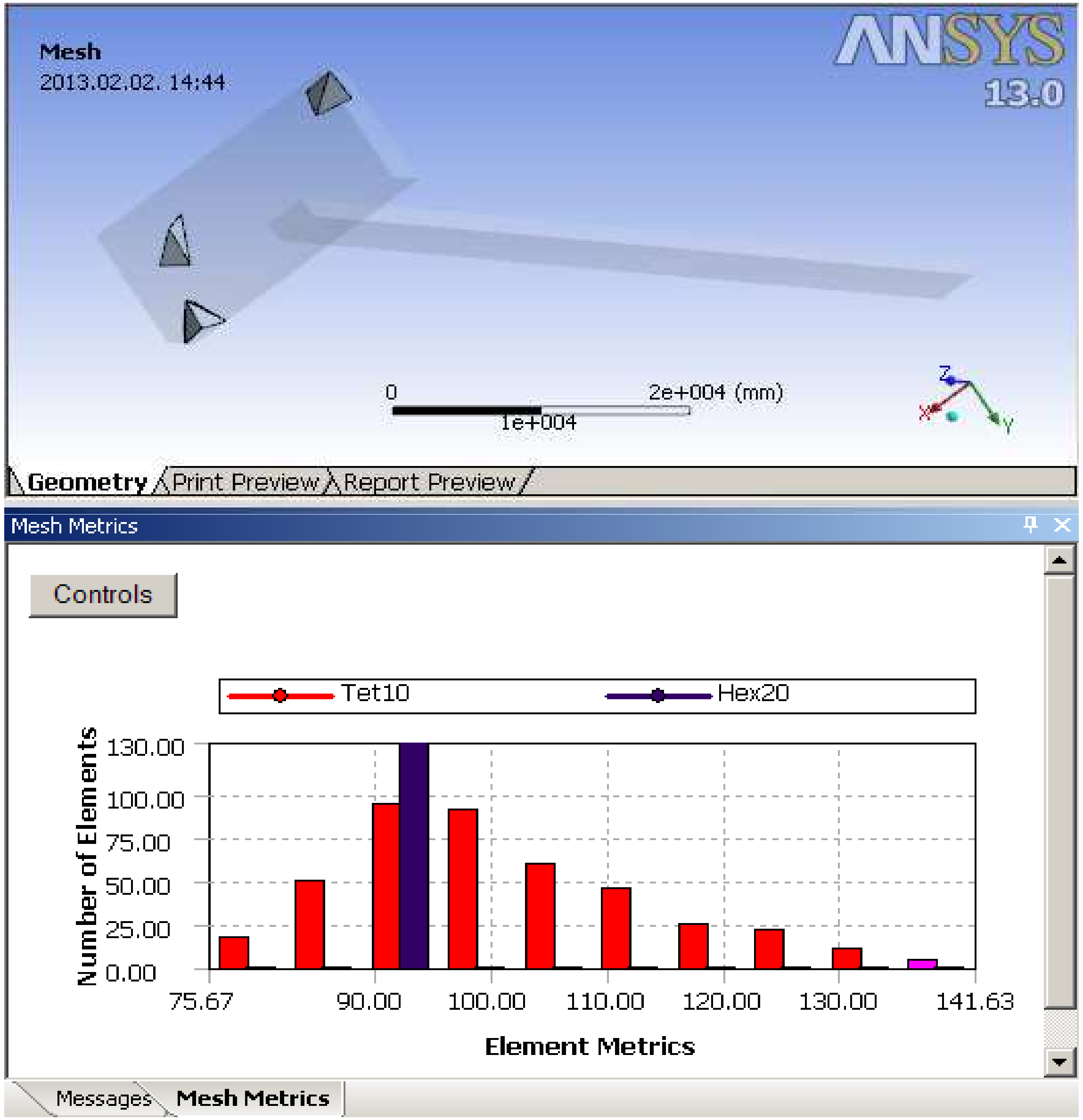


Figure: Parallel Deviations for Quadrilaterals



Ignoring midside nodes, unit vectors are constructed in 3-D space along each element edge, adjusted for consistent direction, as demonstrated in Figure: Parallel Deviation Unit Vectors. For each pair of opposite edges, the dot product of the unit vectors is computed, then the angle (in degrees) whose cosine is that dot product. The parallel deviation is the larger of these 2 angles. (In the illustration above, the dot product of the 2 horizontal unit vectors is 1, and acos (1) = 0°. The dot product of the 2 vertical vectors is 0.342, and acos (0.342) = 70°. Therefore, this element's parallel deviation is 70°.)The best possible deviation, for a flat rectangle, is 0°. Figure: Parallel Deviations for Quadrilaterals shows quadrilaterals having deviations of 0°, 70°, 100°, 150°, and 170°.

Maximum Corner Angle



The maximum angle between adjacent edges is computed using corner node positions in 3-D space. (Midside nodes, if any, are ignored.) The best possible triangle maximum angle, for an equilateral triangle, is 60°. Maximum Corner Angles for Triangles shows a triangle having a maximum corner angle of 165°. The best possible quadrilateral maximum angle, for a flat rectangle, is 90°. Maximum Corner Angles for Quadrilaterals having maximum corner angles of 90°, 140° and 180°.

Maximum Corner Angle

Figure: Maximum Corner Angles for Triangles

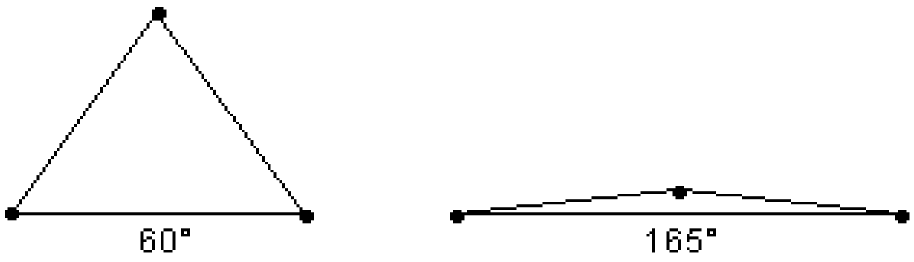
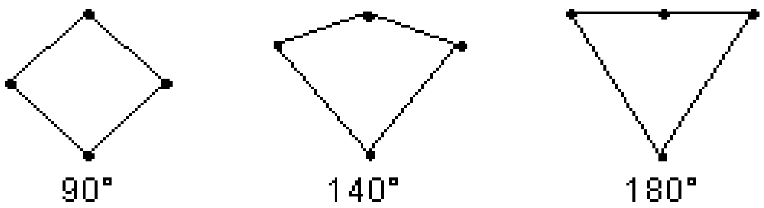


Figure: Maximum Corner Angles for Quadrilaterals



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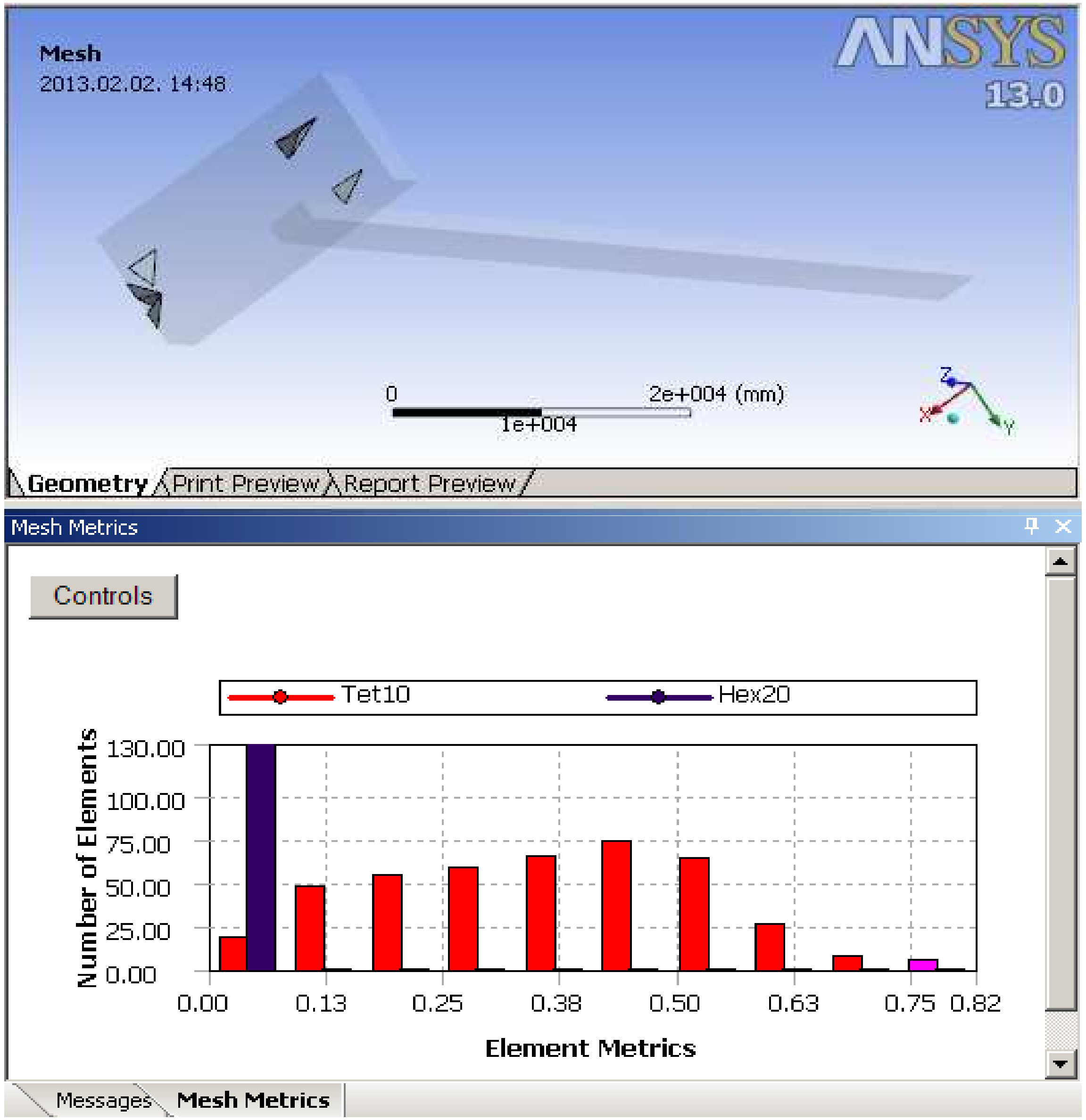
Skewness



Skewness is one of the primary quality measures for a mesh. Skewness determines how close to ideal (i.e., equilateral or equiangular) a face or cell is. According to the definition of skewness, a value of 0 indicates an equilateral cell (best) and a value of 1 indicates a completely degenerate cell (worst). Degenerate cells (slivers) are characterized by nodes that are nearly coplanar (collinear in 2D).

Highly skewed faces and cells are unacceptable because the equations being solved assume that the cells are relatively equilateral/equiangular.

Equilateral-Volume-Based Skewness

In the equilateral volume deviation method, skewness is defined as

$$\text{Skewness} = \frac{\text{Optimal Cell Size - Cell Size}}{\text{Optimal Cell Size}}$$

where, the optimal cell size is the size of an equilateral cell with the same circumradius.

Normalized Equiangular Skewness

In the normalized angle deviation method, skewness is defined (in general) as

$$\max\left[\frac{\theta_{max}-\theta_e}{180-\theta_e}, \frac{\theta_e-\theta_{min}}{\theta_e}\right]$$

where

θ_{max} = largest angle in the face or cell

θ_{min} = smallest angle in the face or cell

θ_e = angle for an equiangular face/cell (e.g., 60 for a triangle, 90 for a square)

Skewness is one of the primary quality measures for a mesh. Skewness determines how close to ideal (i.e., equilateral or equiangular) a face or cell is. According to the definition of skewness, a value of 0 indicates an equilateral cell (best) and a value of 1 indicates a completely degenerate cell (worst). Degenerate cells (slivers) are characterized by nodes that are nearly coplanar (collinear in 2D).

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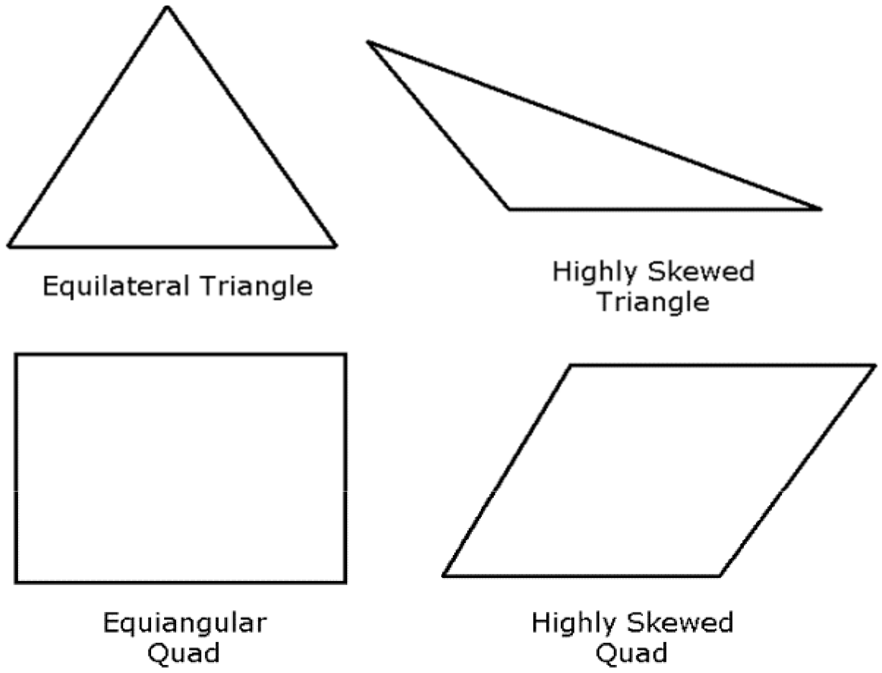
Skewness

Figure: Ideal and Skewed Triangles and Quadrilaterals



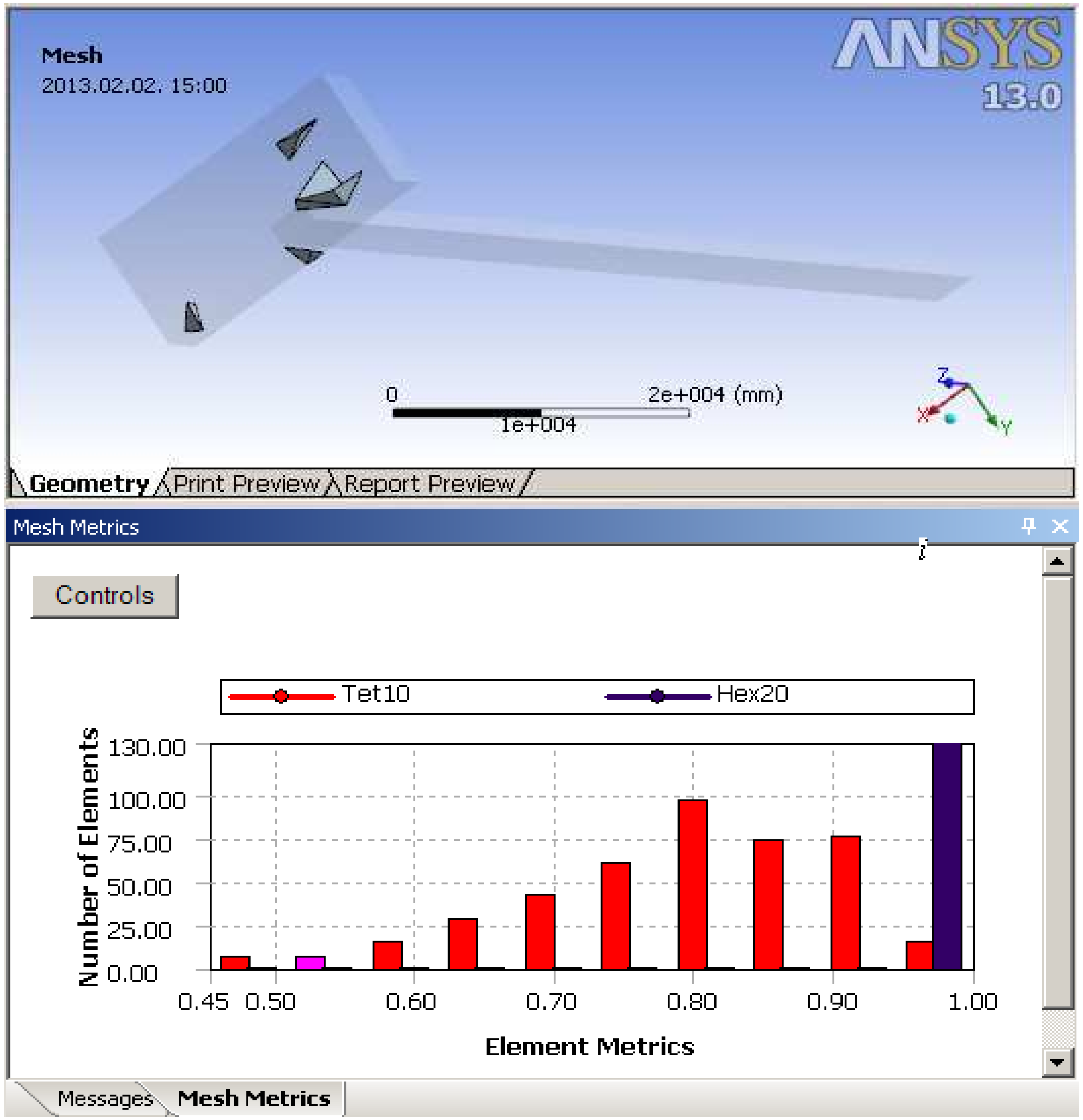
The following table lists the range of skewness values and the corresponding cell quality.

Value of Skewness	Cell Quality
1	degenerate
0.9 — <1	bad (sliver)
0.75 — 0.9	poor
0.5 — 0.75	fair
0.25 — 0.5	good
>0 — 0.25	excellent
0	equilateral

Skewness is one of the primary quality measures for a mesh. Skewness determines how close to ideal (i.e., equilateral or equiangular) a face or cell is. According to the definition of skewness, a value of 0 indicates an equilateral cell (best) and a value of 1 indicates a completely degenerate cell (worst). Degenerate cells (slivers) are characterized by nodes that are nearly coplanar (collinear in 2D).

Highly skewed faces and cells are unacceptable because the equations being solved assume that the cells are relatively equilateral/equiangular.

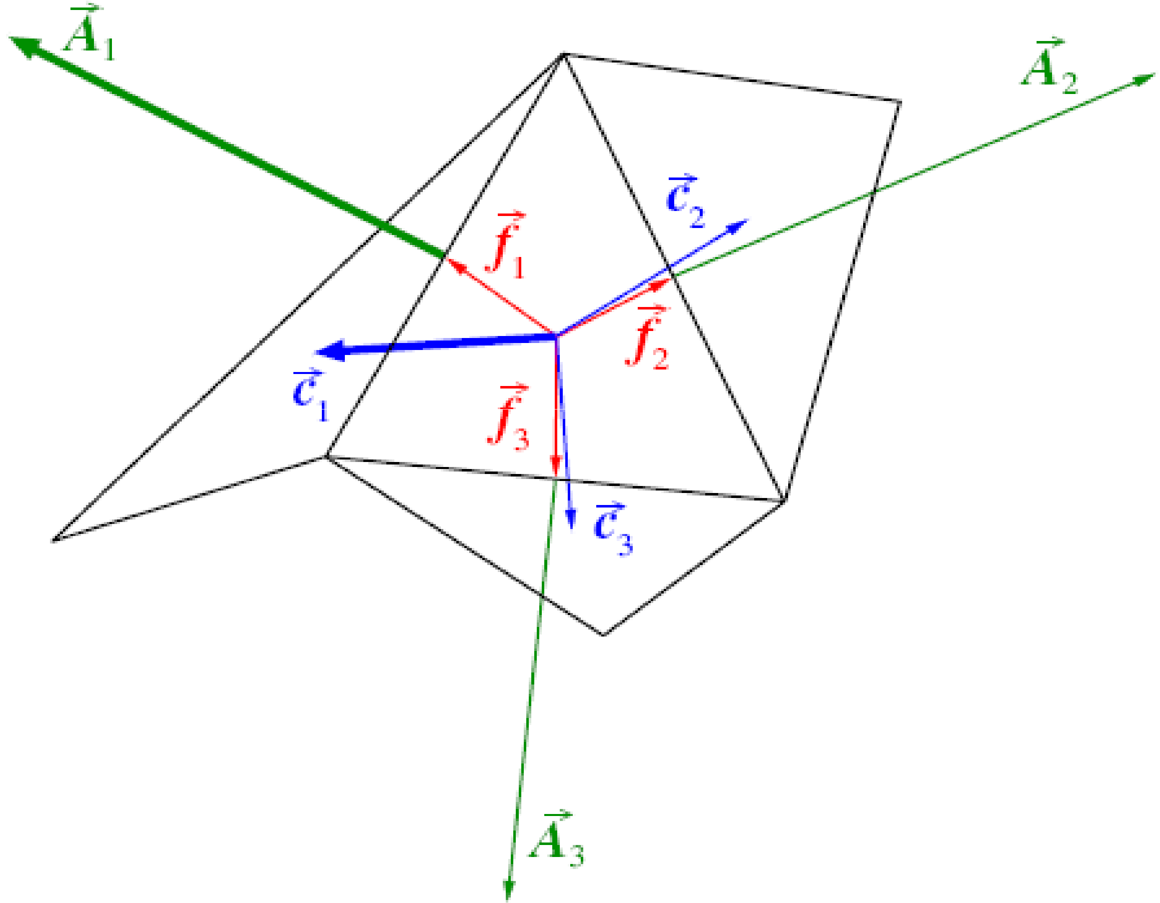
Orthogonal Quality



The quality of the mesh plays a significant role in the accuracy and stability of the numerical computation. Regardless of the type of mesh used in your domain, checking the quality of your mesh is essential. One important indicator of mesh quality is a quantity referred to as the orthogonal quality.

Orthogonal Quality

Figure: Vectors Used to Compute Orthogonal Quality for a Cell



Orthogonal Quality

The quality of the mesh plays a significant role in the accuracy and stability of the numerical computation. Regardless of the type of mesh used in your domain, checking the quality of your mesh is essential. One important indicator of mesh quality is a quantity referred to as the orthogonal quality. In order to determine the orthogonal quality of a given cell, the following quantities are calculated for each face:

the normalized dot product of the area vector of a face ($\vec{A_i}$) and a vector from the centroid of the cell to the centroid of that face ($\vec{f_i}$):

$$\frac{\vec{A}_i \cdot \vec{f}_i}{\left|\vec{A}_i\right|\left|\vec{f}_i\right|}$$

the normalized dot product of the area vector of a face ($\vec{A_i}$) and a vector from the centroid of the cell to the centroid of the adjacent cell that shares that face ($\vec{c_i}$):

$$\frac{\vec{A}_i \cdot \vec{c}_i}{\left|\vec{A}_i\right|\left|\vec{c}_i\right|}$$

The minimum value that results from calculating Equation 1and Equation 2 for all of the faces is then defined as the orthogonal quality for the cell. Therefore, the worst cells will have an orthogonal quality closer to 0 and the best cells will have an orthogonal quality closer to 1.

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Thank you for your kind attention.

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